THE DIGITAL CITY OF TOMORROW

AI PROTOTYPE SURFACE DETECTION

MÖNCHENGLADBACH

WWW.SMARTCITY.MG

INTRODUCTION

The goal of artificial intelligence prototype at hand is to recognize the substrate from aerial imagery (e.g., drone orthophotos). The resulting information can be integrated into a Geo-Information System (GIS). This enables the examination of discrepancies in existing datasets and changes in the urban landscape over a specific timeframe.

The potential applications of such an evaluation are diverse. From intelligent green area irrigation/long-term monitoring, to road damage detection, and the identification of unauthorized creation of gravel gardens or illegal expansion of farmland at the expense of road widths, there are various use cases possible.

The significant advantage of a software-driven solution lies in its significantly faster, semi-automated analysis. To provide the greatest possible value for urban development, the areas should be examined at recurring intervals. Manual measurement would be inconceivable in this context. The entire process can be automated through AI.

The Surface Detection project adopts this approach and aims to use AI to identify the different surfaces of Mönchengladbach. In this feasibility study, distinctions are made between solid pathways, paved roads, and lawns. Manhole covers and trees have received their own respective categories as well.

The development is a collaboration between the City of Mönchengladbach and Masasana GmbH.

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PROJECT HISTORY SO FAR

Review and analysis of existing data sources:
In recent years, the city of Mönchengladbach has already generated extensive drone footage of very high data quality.

Creating new data sources:
Since the previous recordings were made during the winter months, when the trees were without leaves, it was agreed to generate additional data in a newly agreed project area. The decision to fly over the city forest emerged from various discussions. One of the reasons for choosing this project area was to highlight challenges and solutions for capturing aerial images during different seasons.

city forest in summer

city district "Westend" in winter

Especially when considering the analysis over an extended time horizon, it should be possible to conduct evaluations independent of the season. Therefore, from the outset, this factor should be taken into account in the development of the AI.

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Labeling of the images:
In order to train the AI, the available image data needs to be labeled. During this process, the AI is informed about the type of terrain in each area.
The open-source software used for this purpose is called Labelstudio.

In order to facilitate labeling and keep the computational requirements of the algorithms as low as possible, the individual project areas and the resulting orthophotos were converted into small 1000x1000 pixel images. Sections where only white areas are visible were previously sorted out and not included in the labeling process.

During the project, it became apparent that the Westend project area had already been fully surveyed and incorporated into the Geographical Information System (GIS) of the city of Mönchengladbach. After a thorough examination of the existing data and confirming its feasibility, it was decided to further process the data available in Geo-JSON format.

In the programmatic processing of image and Geo-JSON data, an initial mapping of the geo-references onto the corresponding orthophotos had to be carried out. When the positions and reference information matched, the labels from the GIS needed to be transferred into the labels defined by the project team, and the images were also converted into 1000x1000 pixel images.

AI Training:
The actual AI training could now be applied to the fully labeled images. For this purpose, the Mask R-CNN algorithm in the R50 variant was used, which can be found in the Detectron2 project. The configuration used can be found here.

In addition to the pure detection of the ground cover, the detection of manhole covers was also a criterion of the project. Due to the general similarity of manhole covers, the process used for ground detection was mathematically extended and adapted. This reached a point where the AI showed almost no false positives or false negatives in this area.

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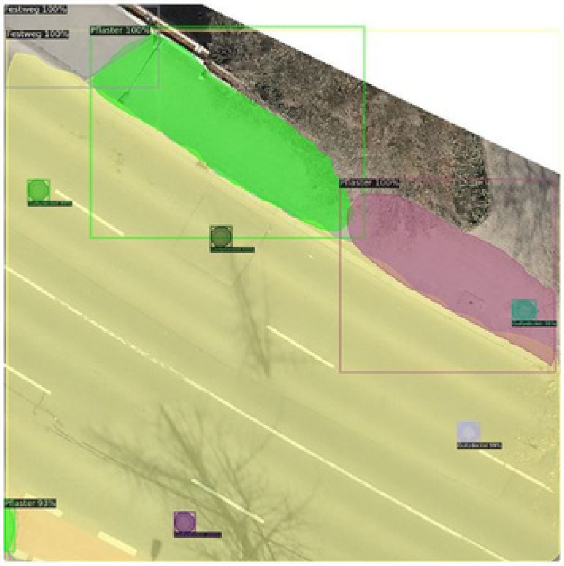
original image



AI-assisted detection

The training of the AI itself was divided into 3 training phases. The completion of each phase provided new insights and helped improve the subsequent model. Let's take a closer look at the different phases.

Phase 1:
At the beginning, the AI had difficulty recognizing the surfaces correctly and comprehensively. In some areas, it detected a solid path even when there was none (false positives), and in other areas, it failed to detect one even when it was present (false negatives). At this stage, a total of 729 areas were used for training, all exclusively from Westend. Solid and paved paths dominated the Westend dataset, providing the AI with limited opportunities to learn about other types of ground cover. This is why Phase 1 resulted in the detection of mostly solid and paved paths.

Phase 2:
In Phase 2, an extended training was conducted with corrected values, including data from Westend. During this phase, the AI made progress in achieving a more comprehensive detection, which recognized both a larger number and a more accurate representation of the actual ground cover.

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Phase 3:
The third training of the AI made it even more reliable and more accurate in recognizing the respective surfaces. This time, over 2000 areas were used, coming from both Westend and Rheindahlen. By adding data from Rheindahlen, the recognition rate of other ground types, in addition to solid and paved paths, significantly increased.

One noticeable aspect in the sample images is that in Phase 3, the same area was categorized as a different type of surface. In Phase 1 and 2, it was recognized as a solid path in the middle, while in Phase 3, it was categorized as paving. A closer look at a section of the original image shows that it is indeed paving, even though it is very difficult to discern.

Note on Data Processing:
At this point, we would like to highlight a particular aspect when working with large datasets from different sources. The provided drone images still include areas with Geroweiher.
However, the images stored in the GIS were cropped due to construction work, which is why Geroweiher is not visible in these images. Nevertheless, the survey data is available in the area around Geroweiher. Therefore, we observed the unique phenomenon where we have labels for which only white areas exist.

Behind the manually labeled areas, the AI has actual objects to be used for training. If the images from the first example had been used, we would have trained the AI to recognize white areas as pavement, road, etc. This should ideally be noted and avoided.

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LEARNINGS

Various methods were applied for AI training, and data from both the labeling tool and the GIS of the city of Mönchengladbach were used for training. It was observed that the data from the Geographical Information System (GIS) was significantly more detailed and better documented.

Creating such well-processed data manually using LabelStudio would not have been possible due to many technical limitations of the software. Therefore, it was not a big surprise that the AI model worked significantly better with this data.

The AI detects various parts of the image, and there can be overlapping areas. It often happens, for example, that an area is adjacent to another area with the same label. In further development, in addition to improving the AI model, emphasis should be placed on result transformation. For instance, all areas of type 'pavement' could be grouped together to create a unified large area.

Another notable aspect is that the deduction does not produce straight edges, as might be common in geographical information systems. In future development, a method should be developed to achieve this 'edge smoothing.'

Finally, it's worth mentioning that the underlying data quantity and quality significantly influence the results of the AI. During the labeling process, we found that the categorization of areas through the open-source tool had some weaknesses.

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CONCLUSION

This feasibility study has demonstrated how AI algorithms can be used for urban planning purposes and help significantly reduce manual efforts, even with a relatively small dataset.

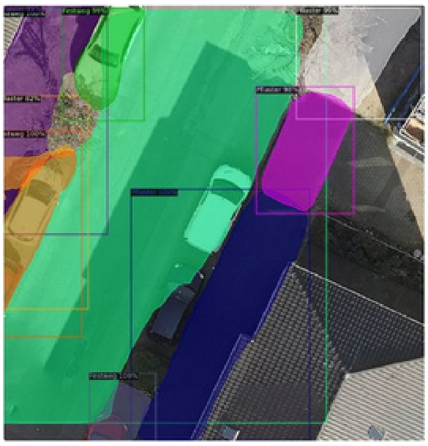
However, the project needs further development and continuous monitoring or validation by a human observer. Ultimately, the data generated should provide added value to the public. In the project's further development, a concept should also be developed for how the generated data can flow back into a GIS, for example, as GEO-JSON.
Ultimately, it can be assumed that the effort required to create such datasets can be continually reduced with the project's ongoing development.

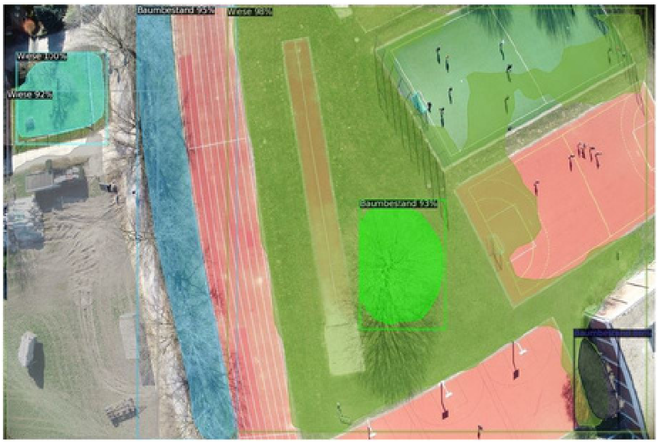
It can also be assumed that with a larger dataset available for training, the results will be significantly better.

THE CITY OF MÖNCHENGLADBACH IS CURRENTLY LOOKING FOR CITIES INTERESTED IN THE COLLABORATIVE DEVELOPMENT OF THIS AI.

IF YOU ARE INTERESTED, PLEASE FEEL FREE TO CONTACT US AT SMARTCITY@MOENCHENGLADBACH.DE.

Additional images based on the current AI development stage:





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